Exploring the effect of Multimodal Interventions on Cognitive and Meta-Cognitive abilities of middle school students: A Psychological study

SYNOPSIS

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DEEPANJALI SHARMA, PH2020- 174

Under the supervision of

Dr. Anindita Das

Associate Prof., LNIPE Gwalior

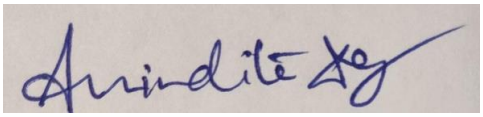
DEPT. OF PHYSICAL EDUCATION PEDAGOGY
LAKSHMIBAI NATIONAL INSTITUTE OF PHYSICAL EDUCATION,

CERTIFICATE

I hereby declare that the short synopsis titled "Exploring the effect of Multimodal Interventions on Cognitive and Meta- Cognitive abilities of middle school students: A Psychological study" is being submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Physical Education under the Dept. of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, Gwalior of the academic year 2022-23.

It is a bona fide record of original work carried out under the supervision of Dr. Anindita Das and has not been submitted in full or part to any other university or institute for a degree or diploma.

Deepanjali Sharma



Dr. Anindita Das
Associate Professor,
Dept. of Physical Education Pedagogy

(Chairman, DRC)

Abstract

This study aims to investigate the impact of multimodal physical training interventions namely continuous training, plyometric training, and strength training on the cognitive and meta-cognitive abilities of middle school students aged 11 to 14 years. Grounded in the psychological framework of cognitive development and self-regulated learning, the research adopts an experimental design with 80 participants divided into four groups: three experimental groups undergoing respective physical training protocols and one control group. The study evaluates five core cognitive abilities memory, awareness, understanding, reasoning, and problem-solving and four meta-cognitive skills planning, implementation, monitoring, and evaluation through standardized cognitive and meta-cognitive assessment tools. By integrating physical education and psychological analysis, the research seeks to establish the role of structured physical activity in enhancing mental faculties critical to academic performance and adaptive learning. The findings are expected to provide empirical support for the inclusion of multimodal physical training in educational curricula, emphasizing the holistic development of students. The outcomes will also contribute to refining pedagogical strategies aimed at fostering mental agility, decision-making, and reflective thinking through physical activity.

Key words: Multimodal interventions, continuous training, plyometric training, strength training, cognitive abilities, meta-cognitive abilities

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1. INTRODUCTION

Continuous training is a form of aerobic exercise characterized by sustained, uninterrupted physical activity performed at a consistent intensity over an extended period of time. It is designed to improve cardiovascular endurance, respiratory efficiency, and metabolic function by targeting the aerobic energy system. Typically conducted at moderate intensity—approximately 60–80% of an individual's maximum heart rate—continuous training includes activities such as running, cycling, swimming, or brisk walking, usually lasting 20 minutes or more without rest intervals.The primary physiological goal of continuous training is to enhance the efficiency of oxygen transport and utilization, resulting in increased cardiac output, improved stroke volume, enhanced capillary density, and greater mitochondrial function in skeletal muscle. These adaptations collectively contribute to improved aerobic capacity (VO_2 max), reduced fatigue, and enhanced endurance performance. Furthermore, continuous training contributes positively to mental health. Tomporowski found that aerobic exercise enhances cognitive functioning, reduces symptoms of anxiety and depression, and improves mood and academic performance, particularly in youth populations.

Plyometric training, also known as "explosive training," is a specialized mode of exercise that involves rapid, high-intensity movements designed to enhance muscular power and neuromuscular coordination. It exploits the stretch-shortening cycle (SSC) of muscle action, wherein an eccentric muscle contraction is immediately followed by a concentric contraction, allowing for greater force production. Typical plyometric exercises include squat jumps, bounding, lateral hops, depth jumps, and medicine ball throws.
The core mechanism underlying plyometric training is the use of stored elastic energy and reflex potentiation during the eccentric phase, which contributes to increased force output during the subsequent concentric movement. These neuromuscular responses enhance the explosive capabilities of muscles, making plyometric training particularly beneficial for improving athletic performance in activities that require speed, agility, and power. In educational settings, plyometric training provides a dynamic and engaging means of developing strength, coordination, balance, and proprioception. It is particularly valuable during adolescence, a developmental period in which neuromuscular adaptations are responsive to training stimuli.

Strength training is a systematic form of physical conditioning that involves the application of external resistance to stimulate muscular contraction, resulting in improvements in muscular strength, endurance, hypertrophy, and neuromuscular efficiency. It is a fundamental component of health-related fitness and is widely employed in both athletic and educational contexts for the enhancement of physical performance and general well-being.
The primary objective of strength training is to increase the force-generating capacity of skeletal muscles through progressive overload, which involves gradually increasing the intensity or volume of exercise to elicit physiological adaptations. This training modality can be implemented using various forms of resistance, including free weights (e.g., dumbbells, barbells), resistance machines, bodyweight exercises, elastic bands, and medicine balls. Exercises typically follow specific movement patterns such as squats, lunges, presses, pulls, and lifts, which target major muscle groups either in isolation or through compound movements.

Cognitive abilities are fundamental mental processes that enable individuals to perceive, process, and utilize information. These abilities encompass a wide range of skills, including memory, awareness, understanding, reasoning ability, and problem-solving ability.

Memory: Memory is the ability to encode, store, and retrieve information. It plays a crucial role in learning, as it allows individuals to retain and recall knowledge and experiences. Memory can be divided into three main types: sensory memory, short-term memory, and long-term memory. Sensory memory briefly holds sensory information, while short-term memory maintains information temporarily. Long-term memory is responsible for the long-term storage of information. Memory consolidation and retrieval are complex processes influenced by various factors such as attention, organization, and emotional significance.

Awareness: Awareness refers to the conscious perception and understanding of oneself and the surrounding environment. It involves monitoring and recognizing internal mental states, sensations, and external stimuli. Awareness is a multidimensional construct that encompasses self-awareness, social awareness, and situational awareness. Self-awareness involves introspection and knowledge of one's thoughts, emotions, and actions. Social awareness relates to understanding and empathizing with others' emotions and perspectives. Situational awareness entails being cognizant of the context, risks, and opportunities in one's environment. Enhanced awareness fosters better decision-making, self-regulation, and interpersonal skills.

Understanding: Understanding involves the ability to grasp and make sense of information or concepts. It goes beyond mere memorization and involves comprehension, synthesis, and application of knowledge. Understanding enables individuals to link new information to existing knowledge frameworks, identify patterns, and extract meaning from complex situations. It allows for deeper learning and critical thinking. Effective teaching and learning strategies emphasize fostering understanding rather than rote memorization.

Reasoning Ability: Reasoning ability is the capacity to think logically, analyse information, and draw conclusions based on evidence and principles. It encompasses deductive reasoning, inductive reasoning, and analogical reasoning. Deductive reasoning involves drawing specific conclusions from general principles or premises. Inductive reasoning involves deriving general principles from specific observations or examples. Analogical reasoning involves identifying similarities between different situations and applying knowledge from one context to another. Enhancing reasoning ability involves developing critical thinking skills, evaluating arguments, and detecting biases or fallacies.

Problem-Solving Ability: Problem-solving ability refers to the aptitude for identifying, formulating, and implementing solutions to complex problems. It involves analyzing problems, generating alternative solutions, evaluating their feasibility, and selecting the most appropriate course of action. Effective problem solvers demonstrate creativity, flexibility, and persistence. Problem-solving ability is not limited to specific domains but is applicable across various contexts, from everyday challenges to professional endeavours. It relies on cognitive processes such as information processing, decision-making, and metacognition. Developing problem solving skills enhances adaptive behaviour, fosters innovation, and promotes lifelong learning.

Cognitive abilities, including memory, awareness, understanding, reasoning ability, and problem-solving ability, are integral to human cognition and contribute to our overall intellectual capacity. These factors interact and support each other, influencing our perception, learning, decision-making, and problem-solving skills. Understanding the complexity of cognitive abilities helps us appreciate the multifaceted nature of human intelligence. Nurturing and developing these abilities

through education, training, and practice can enhance cognitive performance, improve critical thinking, and enable individuals to adapt and thrive in an ever-changing world.

Metacognitive skills refer to our ability to think about and regulate our own cognitive processes. They involve higher-order thinking and self-awareness, allowing us to plan, monitor, and evaluate our own thinking and learning. The four key factors—planning skill, implementation skill, monitoring skill, and evaluation skill—are important components of metacognitive skills.

Planning Skill: Planning involves setting goals, organizing tasks, and developing strategies to accomplish them. With effective planning skills, individuals can break down complex tasks into smaller, manageable steps, allocate resources, and create a timeline. This skill helps individuals to structure their thinking and actions towards achieving desired outcomes.

Implementation Skill: Implementation refers to putting the plans into action. It involves executing the strategies and tasks identified during the planning phase. Effective implementation skills require attention to detail, time management, and the ability to adapt to unexpected challenges. Individuals with strong implementation skills can efficiently carry out their plans and make adjustments as needed.

Monitoring Skill: Monitoring involves keeping track of one's progress and assessing the effectiveness of strategies being employed. It includes self-reflection and being aware of one's own cognitive processes and performance. Monitoring skills help individuals identify errors or areas of improvement, make necessary adjustments, and stay on track toward their goals.

Evaluation Skill: Evaluation involves critically assessing the outcomes and results of one's actions and strategies. It requires analyzing the effectiveness of the chosen approaches and determining the degree to which the goals have been achieved. Strong evaluation skills enable individuals to reflect on their performance, learn from their experiences, and make informed decisions for future tasks or situations.

These four key factors—planning, implementation, monitoring, and evaluation—are interrelated and support each other within the framework of metacognitive skills. By developing and honing these skills, individuals can become more effective learners, problem solvers, and decision-makers. Metacognitive skills are essential for self-regulated learning, improving performance, and achieving success in various domains of life.

2. LITERATURE REVIEW

(Patel et al., 2017) has aimed to further elaborate on these two categories of physical exercise and to help decipher which provides the most effective means of promoting CV health. As physical exercise is one of the most effective methods to help prevent cardiovascular (CV) disease and to promote CV health. Aerobic and anaerobic exercises are two types of exercise that differ based on the intensity, interval and types of muscle fibres incorporated. (Faculty of Business Administration, University of Economics.

Prague,Czech et al., 2019) investigated to determine what is the relationship between physical activity and academic achievement of university students. The research is based on a sample of 159 students at Master degree level studying at the Faculty of Business Administration, University of Economics, Prague. The results suggest that aerobic exercise has a positive effect on study results, but only among students. No effects of anaerobic exercise have been found. Study achievement is also negatively influenced by the students' age. The results are in line with prior studies which, however, focused predominantly on pupils and high school students.

(Stern et al., 2019) In a randomized, parallel-group, observer-masked, community-based clinical trial, 132 cognitively normal individuals aged 20–67 with below median aerobic capacity were randomly assigned to one of two 6-month, 4-times-weekly conditions: aerobic exercise and stretching/ toning. Efficacy measures included aerobic capacity; cognitive function in several domains (executive function, episodic memory, processing speed, language, and attention), everyday function, body mass index (BMI), and cortical thickness. Aerobic capacity increased significantly ($\beta = 2.718$; $p = 0.003$), and BMI decreased significantly ($\beta = -0.596$; $p = 0.013$) in the aerobic exercise but not in the stretching/toning condition. Executive function improved significantly in the aerobic exercise condition; this effect was moderated by age ($\beta = 0.018$ SD/y; $p = 0.028$). At age 40, the executive function measure increased by 0.228 SD (95% confidence interval [CI] 0.007–0.448), and by 0.596 SD (95% CI 0.219–0.973) at age 60. Cortical thickness increased significantly in the aerobic exercise group in a left frontal region and did not interact with age. Controlling for age and baseline performance, individuals with at least one APOE e4 allele showed less improvement in executive function with aerobic exercise ($\beta = 0.5129$, 95% CI 0.0381–0.988; $p = 0.0346$). This randomized clinical trial demonstrates the efficacy of aerobic exercise for cognition in adults age 20–67. The effect of aerobic exercise on executive function was more pronounced as age increased, suggesting that it may mitigate age-related declines. Increased cortical thickness suggests that aerobic exercise contributes to brain health in individuals as young as age 20.

(Álvarez-Bueno et al., 2020) aims to quantify the association between aerobic fitness and academic achievement, and determine how different aerobic fitness tests and individual demographic characteristics may modify this association. It includes 41 cross-sectional and 7 longitudinal studies focusing on children and adolescents, from MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database and Web of Science. Pooled effect sizes (ES) were estimated for the association between aerobic fitness and specific domains of academic achievement. Subgroup analyses and meta-regressions were based on aerobic fitness tests and demographic characteristics. The ES for the association between aerobic fitness with language/reading-skills, mathematics-related skills and composite scores, were 0.23 (95% CI: 0.12; 0.34); 0.27 (95% CI: 0.19; 0.36) and 0.28 (95% CI: 0.12; 0.45), respectively. Subgroup analyses by aerobic fitness test modified these associations; additionally, analyses by sex or age showed differences between boys and girls as well as between children and adolescents. Finally,

meta-regressions revealed a slight effect of body mass index on these associations. Cardiorespiratory fitness is positively associated with academic achievement. Associations were dependent on demographic and aerobic fitness test characteristics, being stronger in boys than in girls, and in children than in adolescents.

(Haverkamp et al., 2020) investigated about the effects of physical activity interventions on cognitive outcomes and academic performance in adolescents or young adults. A systematic review with meta-analysis was performed using the following databases: Embase, ERIC, MEDLINE, PsycINFO and Web of Science. Studies had to meet the following criteria: controlled study design, investigating the effects of physical activity interventions on cognitive outcomes and academic performance in healthy adolescents or young adults (12–30 years). Results showed that acute interventions (n=44) significantly improved processing speed (ES=0.39), attention (ES=0.34) and, inhibition (ES=0.32). In a subsequent meta-regression, shorter duration of intervention was significantly associated with greater improvements in attention (β=−0.02) and cognitive flexibility (β=−0.04), whereas age, percentage of boys, intensity and dose were not. Chronic interventions (n=27) significantly improved processing speed (ES=0.30), attention (ES=0.50), cognitive flexibility (ES=0.19), working memory (ES=0.59) and language skills (ES=0.31). In the meta-regression, higher percentage of boys was significantly associated with greater improvements in attention (β=0.02) and working memory (β=0.01) whereas age, duration, frequency, dose and load were not. In conclusion, acute and chronic physical activity interventions might be a promising way to improve several cognitive outcomes and language skills in adolescents and young adults.

(Atakan et al., 2021) Engaged in regular exercise results in a range of physiological adaptations and offered benefits for exercise capacity and health, independent of age, gender or the presence of chronic diseases. Accumulating evidence shows that lack of time is a major impediment to exercise, causing physical inactivity worldwide. This issue has resulted in momentum for interval training models known to elicit higher enjoyment and induce adaptations similar to or greater than moderate-intensity continuous training, despite a lower total exercise volume. Although there is no universal definition, high-intensity interval exercise is characterized by repeated short bursts of intense activity, performed with a “near maximal” or “all-out” effort corresponding to ≥90% of maximal oxygen uptake or >75% of maximal power, with periods of rest or low-intensity exercise. Research has indicated that high-intensity interval training induces numerous physiological adaptations that improve exercise capacity (maximal oxygen uptake, aerobic endurance, anaerobic capacity etc.) and metabolic health in both clinical and healthy (athletes, active and inactive individuals without any apparent disease or disorder) populations. In this paper, a brief history of high-intensity interval training is presented, based on the novel findings of some selected studies on exercise capacity and health, starting from the early 1920s to date. Further, an overview of the mechanisms underlying the physiological adaptations in response to high-intensity interval training is provided.

(Troisi Lopez et al., 2023) conducted a descriptive study comparing Tai Chi practitioners and runners to assess the impact of multimodal physical exercise on visuo-spatial working memory. The findings indicated that individuals engaged in multimodal activities exhibited enhanced visuo-spatial working memory compared to those involved in unimodal exercises, suggesting the cognitive benefits of integrating diverse physical training modalities.

(Wang et al., 2023) proposed a study protocol to assess the effects of exergames on cognitive functions in adolescents with depression. The randomized controlled trial aims to determine whether engaging in interactive physical games can lead to improvements in cognitive abilities,

providing insights into innovative multimodal interventions for mental health and cognitive enhancement.

(Taylor et al., 2023) evaluated the effects of multimodal physical and cognitive fitness training on sustaining mental health and job readiness in a military cohort. The study demonstrated that combining physical workouts with cognitive training and mindfulness practices led to significant improvements in mental well-being and cognitive performance, suggesting the efficacy of integrated training programs.

(Williams et al., 2023) explored the effects of a games-based physical education lesson on cognitive function in adolescents. The study demonstrated that high-fit adolescents showed superior cognition, including quicker response times across various cognitive domains, compared to their lower-fit counterparts. This underscores the potential of integrating varied physical activities to enhance cognitive performance in youth.

(Akil et al., 2024) investigated the cognitive health outcomes of fundamental motor skill applications in children through cooperative learning methods. The study found that incorporating cooperative learning with motor skill activities led to improvements in visual-motor integration and selective attention among children aged 10–11, emphasizing the cognitive advantages of combining physical skills with collaborative learning strategies.

(Zhou et al., 2024) compared the effects of morning versus afternoon school-based high-intensity interval exercise (HIIE) on cognitive function in adolescents. The study found that morning HIIE sessions led to more significant improvements in reaction time and cognitive performance, suggesting that the timing of physical activity can influence its cognitive benefits.

3. STATEMENT OF THE PROBLEM

The purpose of this study is to see the "Exploring the effect of Multimodal Interventions on Cognitive and Meta- Cognitive abilities of middle school students: A Psychological study"

4. RESEARCH QUESTION

What will be the impact on Cognitive and Meta- Cognitive abilities of continuous training, plyometric training, and strength training on middle school students between the age group of 11-14 years?

5. OBJECTIVES OF THE STUDY

1. The objective of the study is to characterize the effect of continuous training, plyometric training and strength training on the cognitive and meta-cognitive abilities of middle school students.
2. To promote the concept of health, fitness, and physical education and enhance the cognitive and meta-cognitive abilities of middle school students.

6. DELIMITATIONS

1. The study will be delimited to middle school students.
2. The study is further delimited to the age group of 11-14 years.
3. The study will be delimited to 80 middle school students, divided into four groups of 20 each—three experimental groups receiving continuous training, plyometric training, and strength training respectively, and one control group.
4. The study will also be delimited to continuous training, plyometric training, and strength training as the treatment.

7. HYPOTHESIS

Based on literature and research, scholars' understanding, the following hypotheses are formulated:-

• Ha1: It is hypothesized that there will be an increment in the cognitive abilities of middle school students.
• Ha2: It is hypothesized that there will be an increment in meta-cognitive abilities of middle school students.

8. DEFINITIONS AND EXPLANATION OF TERMS

CONTINUOUS TRAINING
Continuous training involves steady, uninterrupted aerobic exercise performed at a consistent intensity over an extended period, aiming to improve cardiovascular endurance and aerobic capacity.

PLYOMETRIC TRAINING
Plyometric training consists of explosive movements that utilize the stretch-shortening cycle of muscles—such as jumps, hops, and bounds—to develop power, speed, and neuromuscular coordination.

STRENGTH TRAINING
Strength training is a form of physical exercise that uses resistance—such as weights or body weight—to enhance muscular strength, endurance, and overall functional capacity.

COGNITIVE ABILITIES
Cognitive abilities refer to the mental processes and skills involved in acquiring, processing, and utilizing information. They encompass various functions such as perception, attention, memory, problem-solving, reasoning, and decision-making. These abilities enable individuals to understand, learn, think, and engage in complex cognitive tasks, ultimately influencing their overall intelligence and cognitive functioning.

META-COGNITIVE ABILITIES
Meta-cognitive abilities refer to the higher-level cognitive processes that enable individuals to reflect upon, monitor, and regulate their own thinking. They involve awareness of one's own thoughts, knowledge, and strategies, as well as the ability to plan, set goals, evaluate progress, and make adjustments when necessary. Meta-cognitive abilities play a crucial role in learning, problem-solving, and self-directed learning.

9. SIGNIFICANCE OF THE STUDY

1. The outcome of the study will be useful in enhancing the cognitive and meta-cognitive abilities of middle school students.
2. The study will be helpful in raising awareness about physical fitness, health and lifestyle amongst students.
3. The outcome of the study will be useful in promoting the importance of continuous training, plyometric training, and strength training
4. The findings of the study will also help in designing an appropriate curriculum for the students in order to help them achieve great heights in various aspects of cognitive and meta-cognitive abilities.

10.METHODOLOGY

This chapter describes the selection of subjects, selection of variables, administration of the test, collection of data and statistical techniques for data analysis.

10.1 Selection of Subjects

80 middle school students of age group 11-14 years will be selected as the subjects for this study which are further divided into four groups of 20 each—three experimental groups receiving continuous training, plyometric training, and strength training respectively, and one control group.

10.2 Selection of Variables

The following are the test variables:

A. Cognitive abilities

1. Memory

2. Awareness

3. Understanding

4. Reasoning Ability

5. Problem Solving Ability

B. Meta-cognitive abilities

1. Planning skill

2. Implementation skill

3. Monitoring skill

4. Evaluation skill

10.3 Administration of the test

The questionnaires will be distributed to each subject, and the content of the questionnaire will be explained to the subjects prior responding to the questions.

10.4 Criterion Measure

To find out the level of cognitive abilities in middle school students, Cognitive Ability Test is selected to measure Memory, Awareness, Understanding, Reasoning Ability and Problem-Solving Ability.
To find out the level of meta-cognitive abilities in middle school students, is selected to measure Planning skill, Implementation skill, Monitoring skill and Evaluation skill.

10.5 Data Collection Procedure

The data will be collected for cognitive and meta-cognitive abilities, by administering the respective tests. The test administered at the suitable place where subjects want to and according to the time suitability of the subject. And it will be under the observation of the researcher to ensure that the data collected is reliable each subject responding fairly.

10.6 Statistical Procedure

- Descriptive statistics (mean, standard deviation) will be used to analyse the data.
- Repeated measure ANOVA would be employed at a 0.05 significance level to analyse the effect over time.

11.EXPECTED OUTCOME OF THE RESEARCH

It is expected that the implementation of multimodal physical training interventions specifically continuous training, plyometric training, and strength training will have a significant and positive impact on the cognitive and meta-cognitive abilities of middle school students. Each training modality is anticipated to enhance specific domains of cognition and self-regulation due to their unique physiological and psychological effects. Continuous training, characterized by sustained aerobic activity, is likely to improve memory retention, awareness, and understanding by promoting increased cerebral blood flow, oxygen delivery to the brain, and neuroplasticity. These physiological changes are known to support learning, attention, and information processing in adolescents. Plyometric training, involving high-intensity, explosive movements, is expected to enhance problem-solving and reasoning abilities by improving neural efficiency, coordination, and responsiveness, thereby strengthening students' ability to think quickly and adaptively in dynamic situations. Strength training, through its emphasis on resistance and control, is hypothesized to foster planning and implementation skills by reinforcing goal-oriented behavior, discipline, and task execution all critical elements of meta-cognitive development.

Moreover, all three forms of training are expected to contribute collectively to the development of core meta-cognitive abilities such as monitoring and evaluation. These abilities are essential for self-reflection, academic self-regulation, and adaptive learning strategies. The experiential nature of physical training requiring students to engage in real-time decision-making, strategy adjustment, and performance assessment closely mirrors the components of metacognitive practice. It is also anticipated that participants in the experimental groups will show greater improvement in test

scores measuring planning, implementation, monitoring, and evaluation skills compared to those in the control group, thereby validating the role of structured physical activity in enhancing higher-order thinking processes.

Furthermore, the study is expected to establish a strong empirical link between physical education and psychological development, reinforcing the idea that motor training is not isolated to physical benefits but plays a foundational role in mental and academic growth. The anticipated findings will provide evidence to support the integration of multimodal training modules into school curricula, not only for physical fitness but also as a strategic tool for cognitive and meta-cognitive development. The outcomes are also likely to stimulate further interdisciplinary research and innovation in educational psychology, physical education pedagogy, and school health policy. Overall, this research is expected to offer valuable insights that contribute to the holistic development of students, preparing them to meet both academic and life challenges with enhanced mental agility and self-awareness.

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